National Aeronautics and Space Administration

Material Analysis and System Design for Exploration Life Support Systems

Introduction to ECLSS Air Revitalization Support for Exploration Missions

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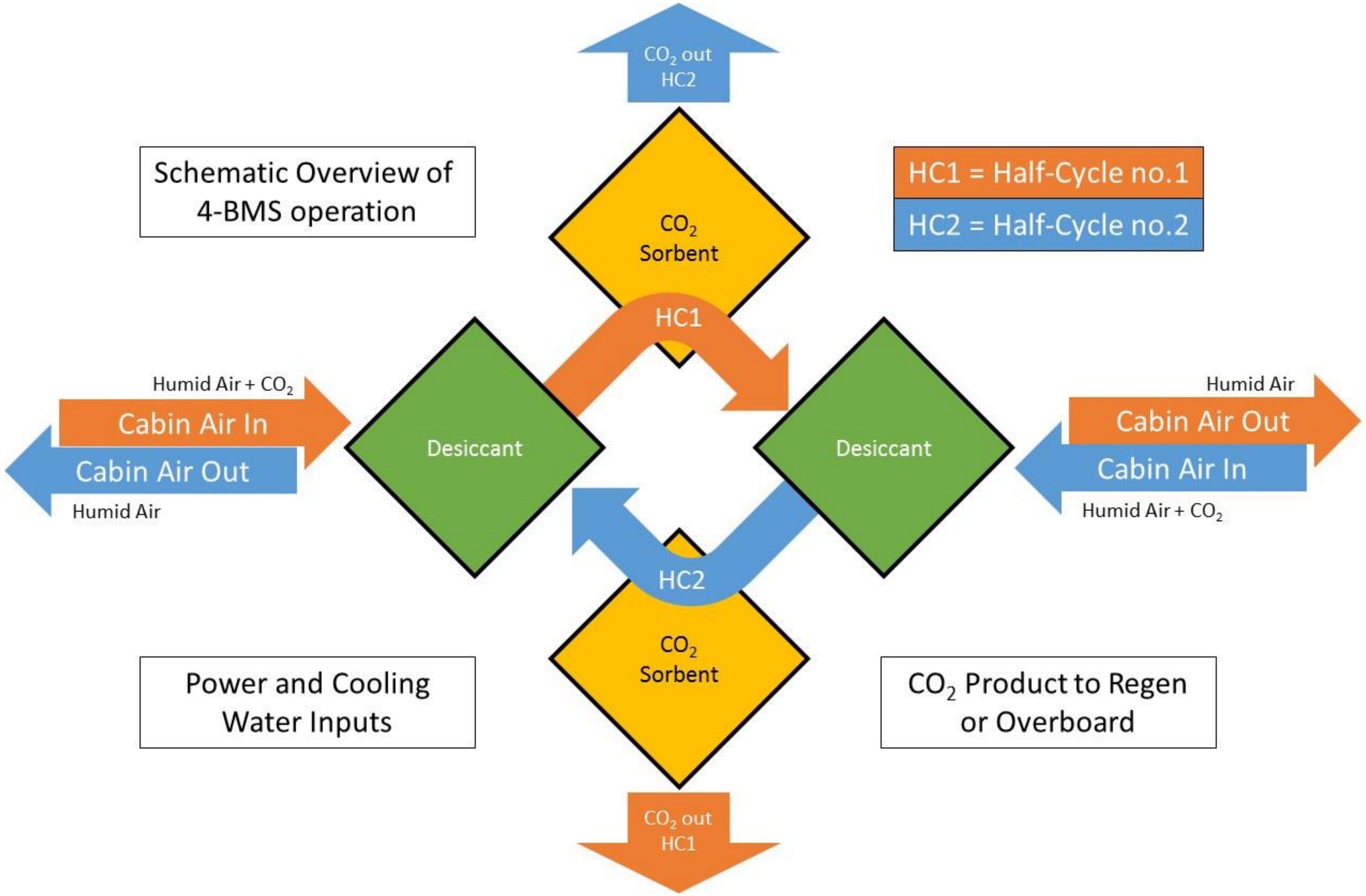
MARSHALL
SPACE FLIGHT CENTER

- Life Support requires many continuous separation systems
  - Waste
  - Water
  - **Air**
    - Accomplished today with a Russian Vozdukh and two American CDRA systems

- CDRA is the flight version of a 4BMS system
  - 4-Bed Molecular Sieve
  - Cyclic operation

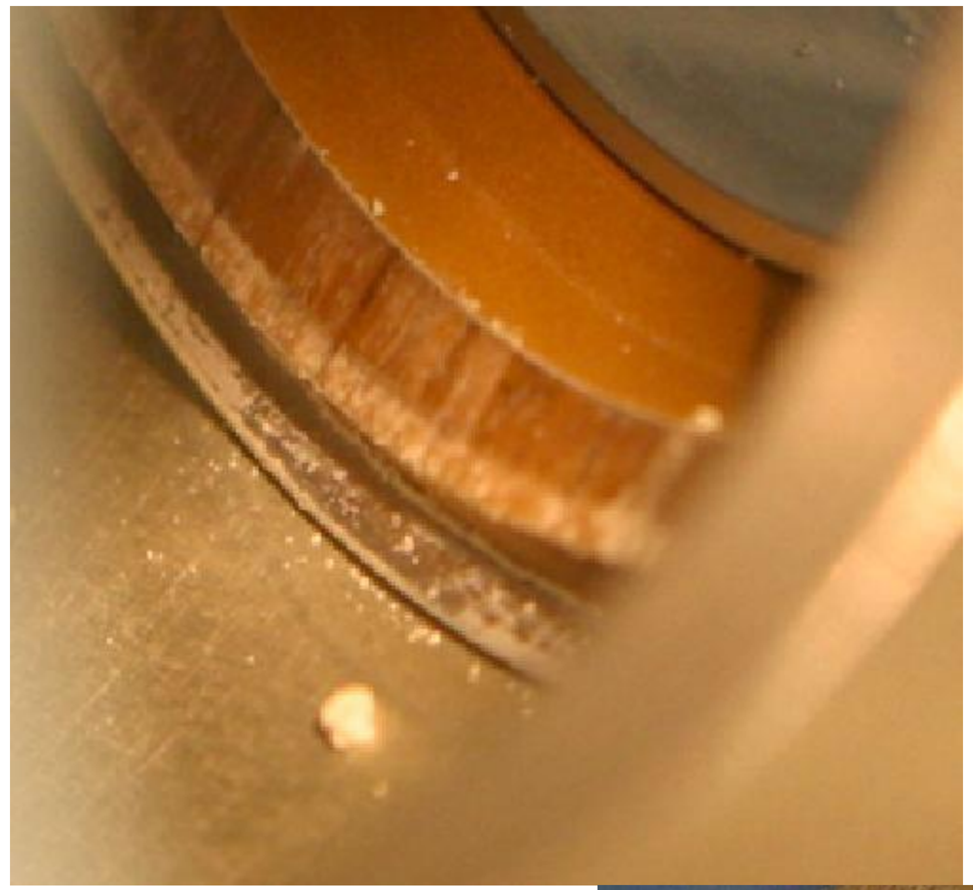
- Separate CO_2 out of humid cabin air
  - High purity product

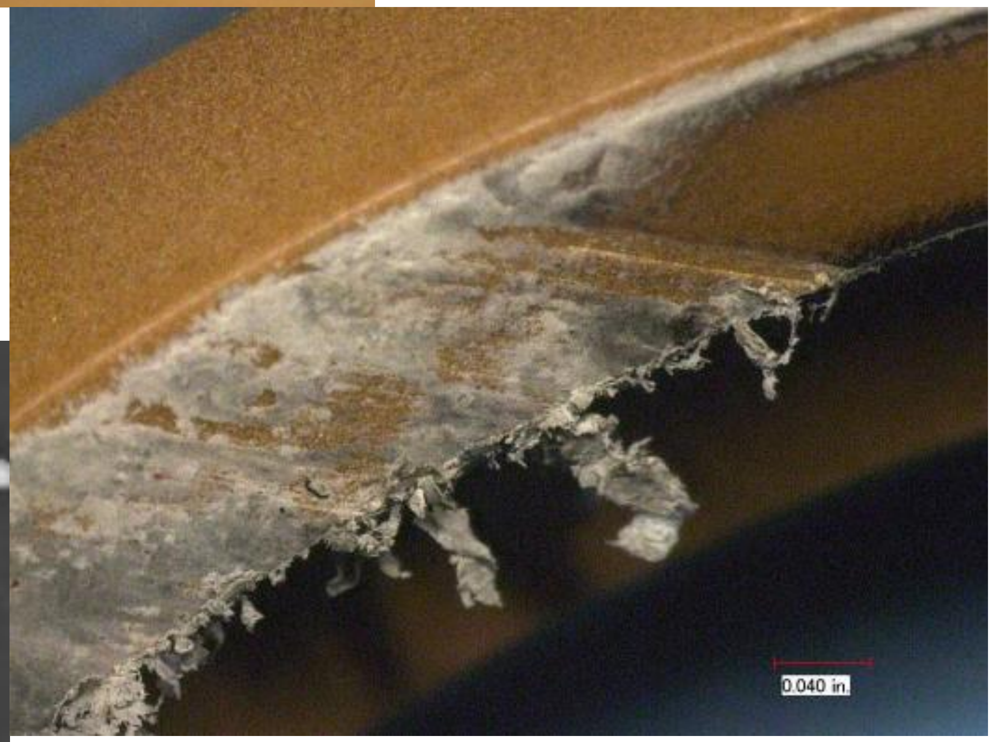


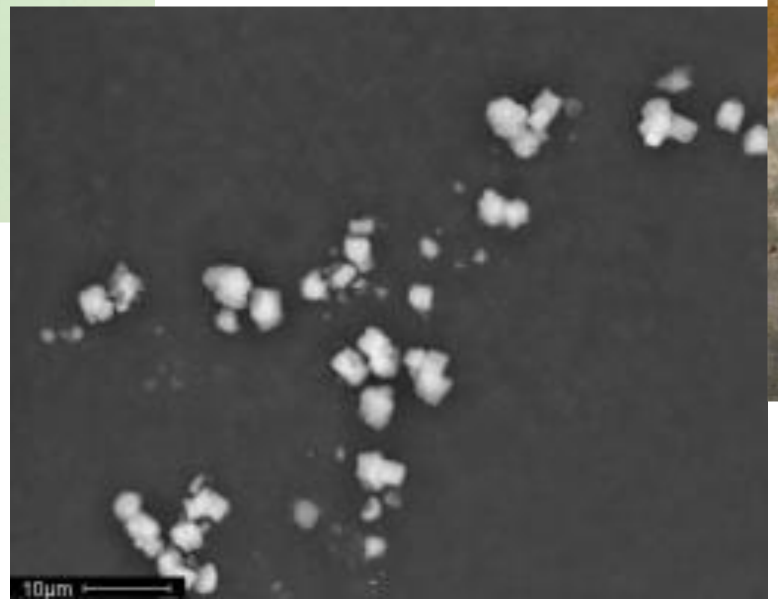
- CDRA is now at iteration 5 due to…

  <u>DUST</u>
  - Many failures
  - Many identified possible causes

- Re-design required
  - Bring the process in house (ES62)
  - Mitigate and avoid all causes of dust







Identifying causes and solutions

- A few directly attributable failures:
  - Dust in valve => valve jamming/leaking
  - Dust on screen => flow blockage
  - Sheet heater delamination => heater short/failure

- Dozens of potential failure causes:
  - Large air velocity and pressure transients
  - Uncompacted voids which allow for free-floating particles and attrition
  - Thermal and moisture induced degradation of sorbents
  - Operating at the thermal limits of various components such as heater sheets and O-rings
  - Operator error due to difficult assembly of system

Final Goal is reliable operation for <u>4 crew</u> for 3 years.

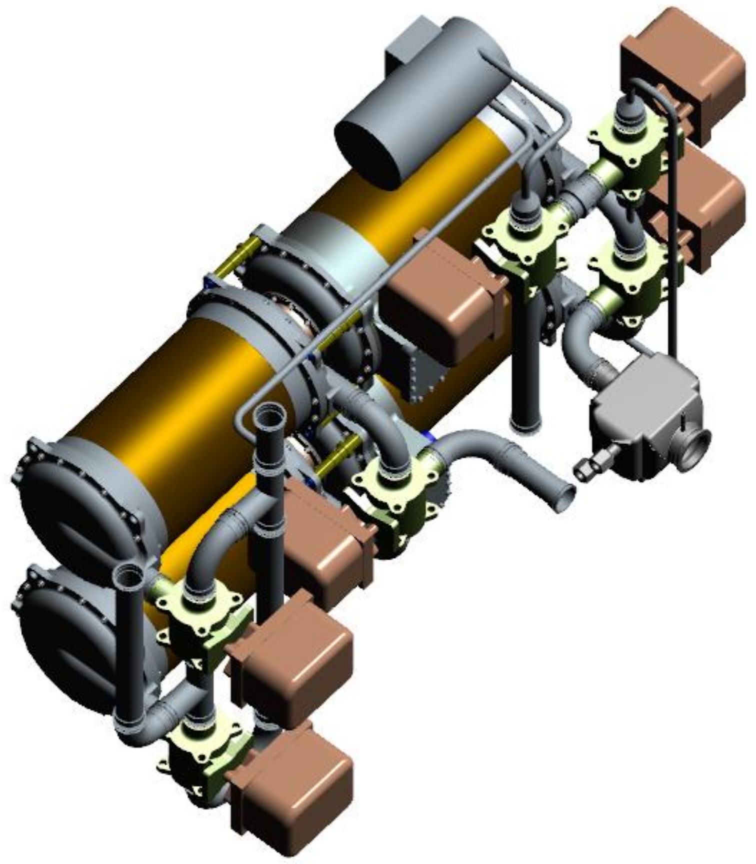
Full redesign of components for the future 4BMS

– Retain tested and proven operating architecture of CDRA
– Provide remedies for each known and suspected failure

Original flight-like test beds in 4BMS test stand

New components in build

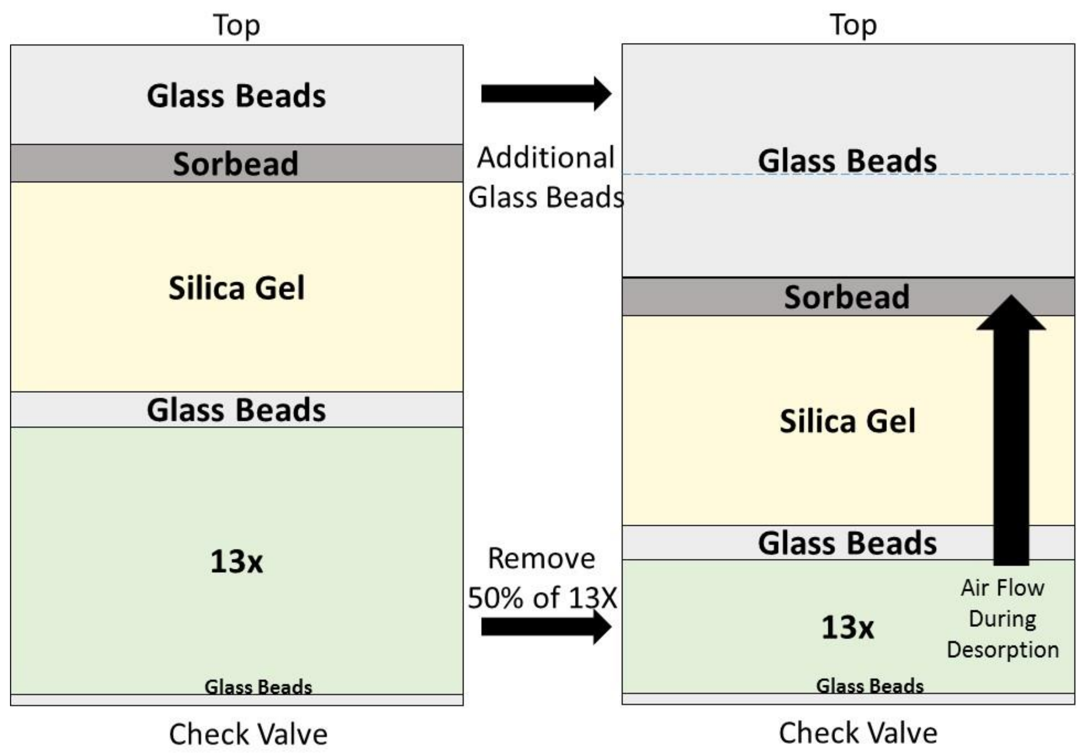
Target flight-like configuration



What goes into the decision process?

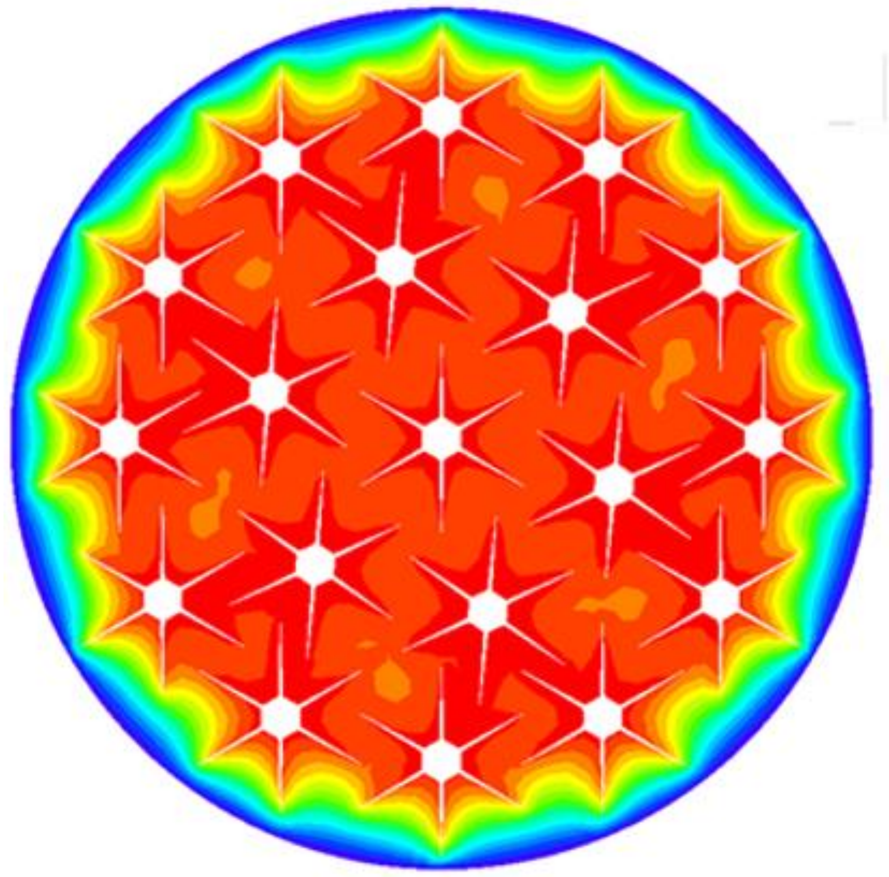
Sorbent selection

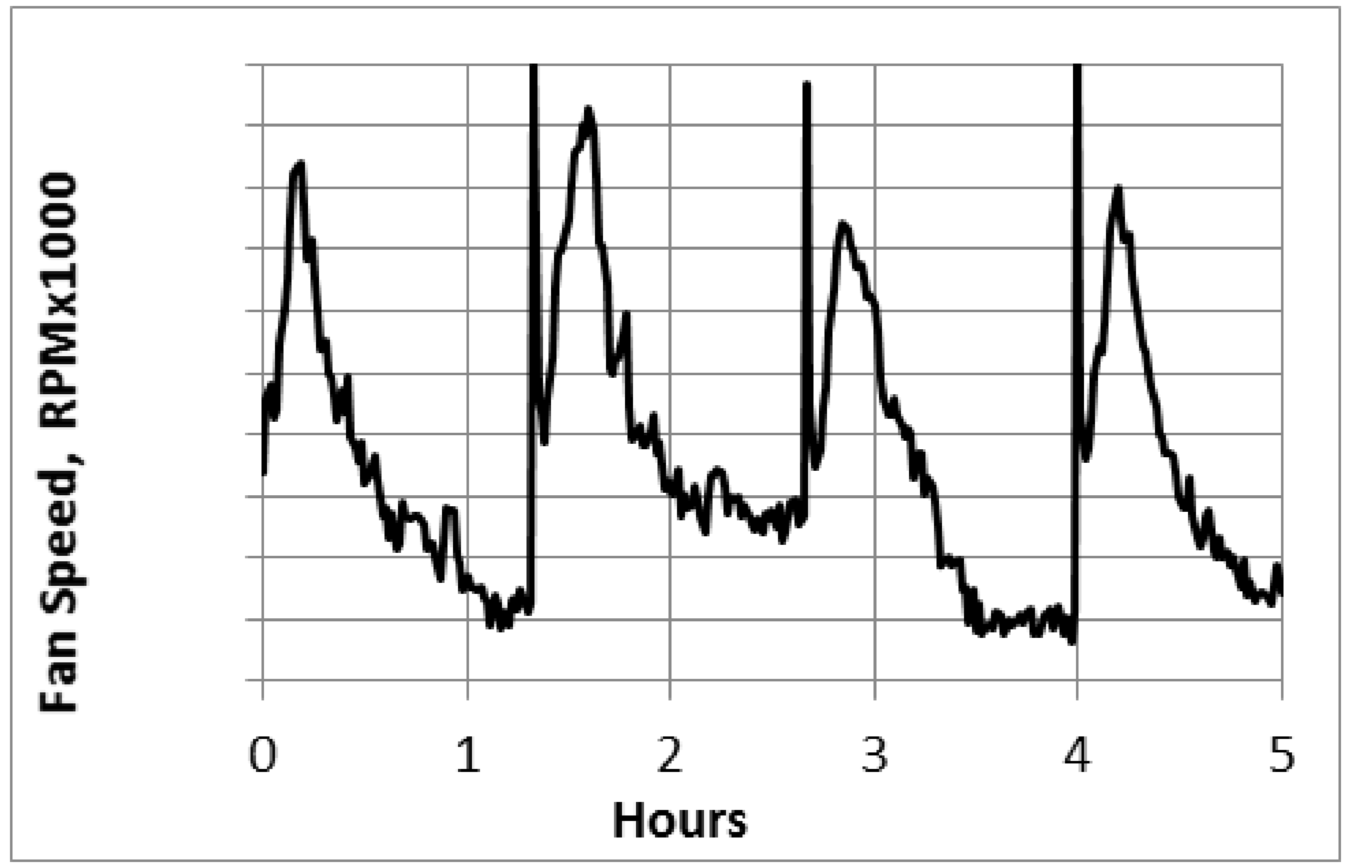
Material Type	Sorbent Name	Use/Potential Use	Form Factor	Pore size	Notes
Silica Gel	Grace Grade 40	Bulk Desiccant	Granular	Microporous	used in CDRA
Silica Gel	Grace SG B125	Bulk Desiccant	Beads	Microporous	used in CDRA
Silica Gel	BASF Sorbead H	Bulk Desiccant	Beads	Microporous	
Silica Gel	BASF Sorbead R	Bulk Desiccant	Beads	Microporous	
Alumino-Silica Gel	BASF Sorbead WS	Guard Layer	Beads	Microporous	Misting Stable, used in CDRA
Activated Alumina	BASF F200	Bulk Desiccant	Beads	Mesoporous	Misting Stable
Molecular Sieve	UOP ASRT 1995 and ASRT 2005	CO_2 sorbent	Pellets	5Å	CaA Zeolite, used in CDRA
Molecular Sieve	UOP RK-38	CO_2 sorbent	Beads	5Å	CaA Zeolite, used in CDRA
Molecular Sieve	Grace MS 564	Residual Desiccant	Beads	3Å	KA Zeolite
Molecular Sieve	Grace MS 514	Residual Desiccant	Beads	4Å	NaA Zeolite
Molecular Sieve	UOP UI-94	Residual Desiccant	Pellets	4Å	NaA Zeolite
Molecular Sieve	Grace MS 522	CO_2 sorbent	Beads	5Å	CaA Zeolite
Molecular Sieve	Grace MS 544	CO_2 sorbent, Residual Desiccant	Beads	10Å	NaX Zeolite, used in CDRA
Molecular Sieve	BASF 5A	CO_2 sorbent	Beads	5Å	CaA Zeolite
Molecular Sieve	BASF 5A BF	CO_2 sorbent	Binder-free Beads	5Å	CaA Zeolite
Molecular Sieve	BASF 13X	CO_2 sorbent, Residual Desiccant	Beads	10Å	NaX Zeolite
Molecular Sieve	BASF 13X BF	CO_2 sorbent	Binder-free Beads	10Å	NaX Zeolite
Molecular Sieve	UOP APGIII	CO_2 sorbent	Beads	10Å	NaX Zeolite
Molecular Sieve	UOP VSA-10	CO_2 sorbent	Beads	10Å	LiLSX Zeolite
Molecular Sieve	Tosoh NSA-700	CO_2 sorbent	Pellets	10Å	LiLSX Zeolite



System sizing

Heater core redesign and optimization

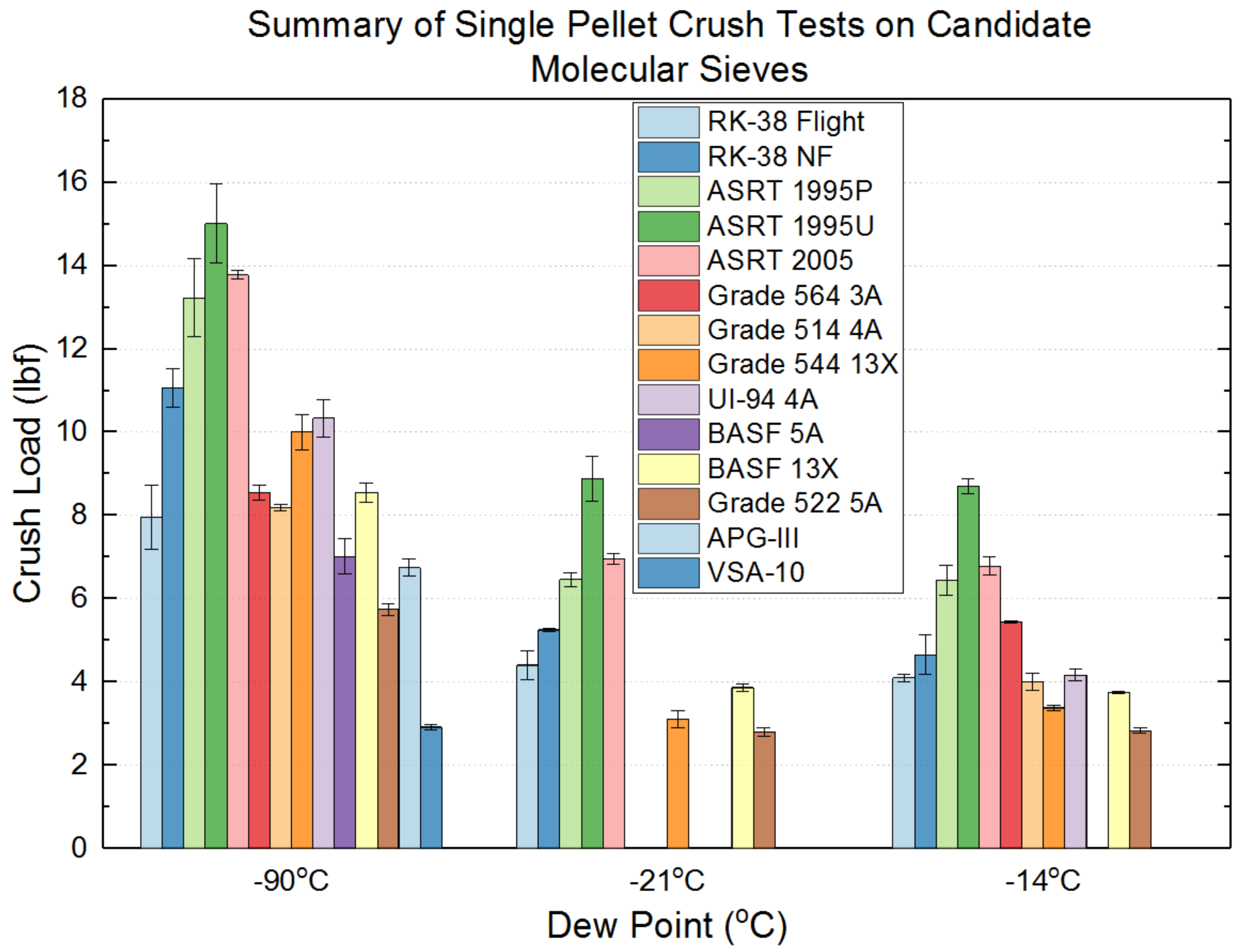


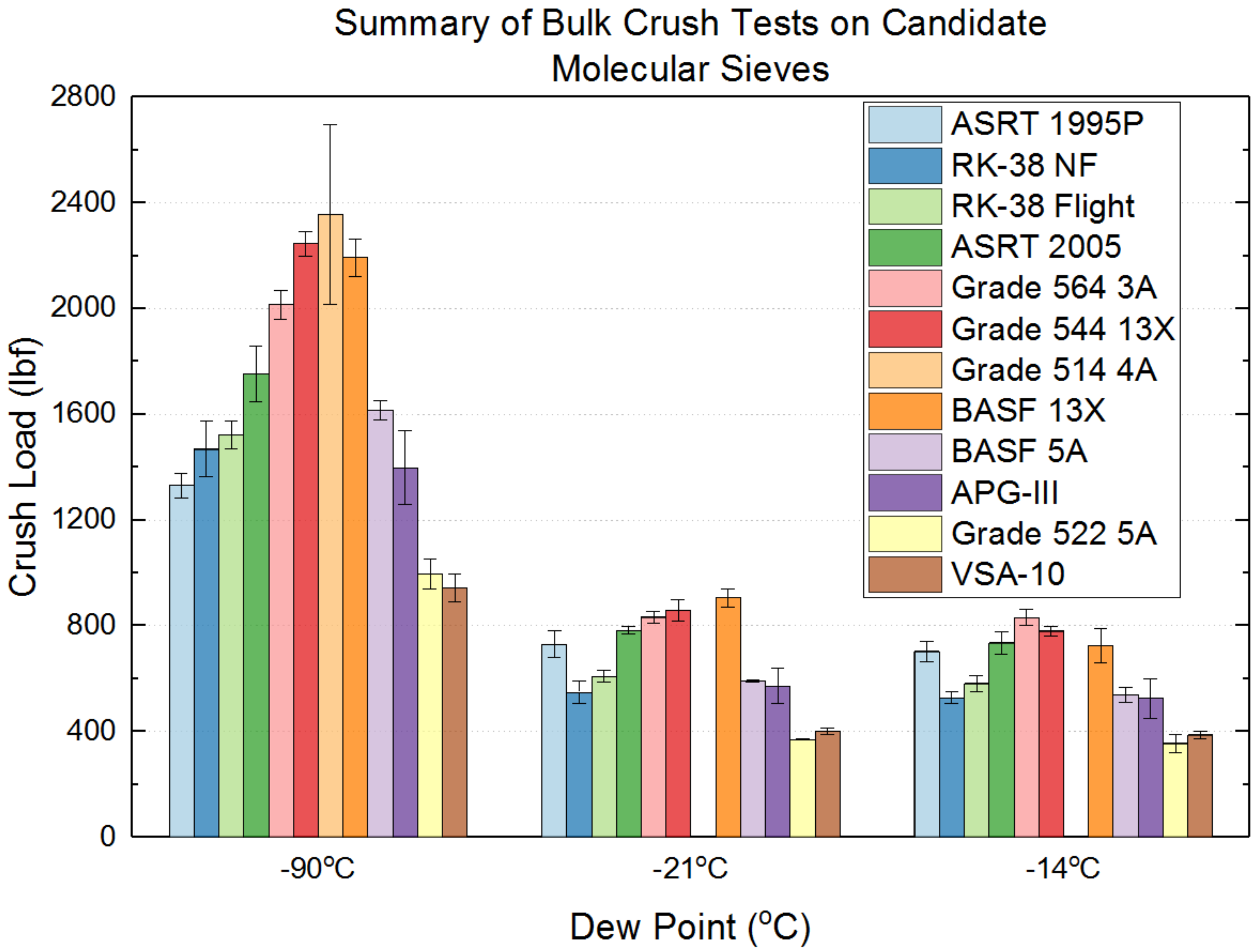


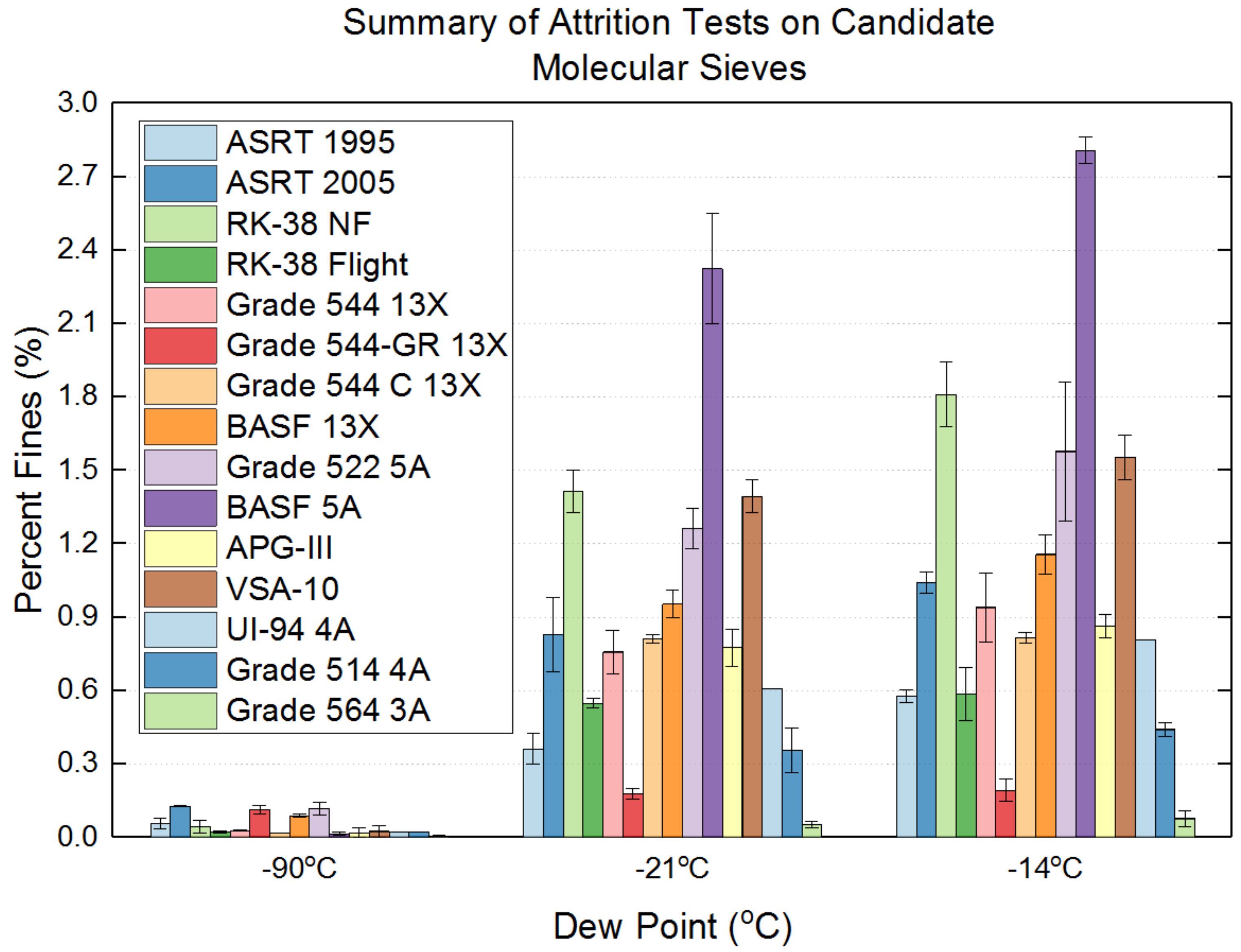
Design to address problems at transitions

- What goes into the decision process?
  - **Sorbent selection**
  - System sizing
  - Heater core redesign and optimization
  - Design to address problems at transitions

Sorbent Robustness

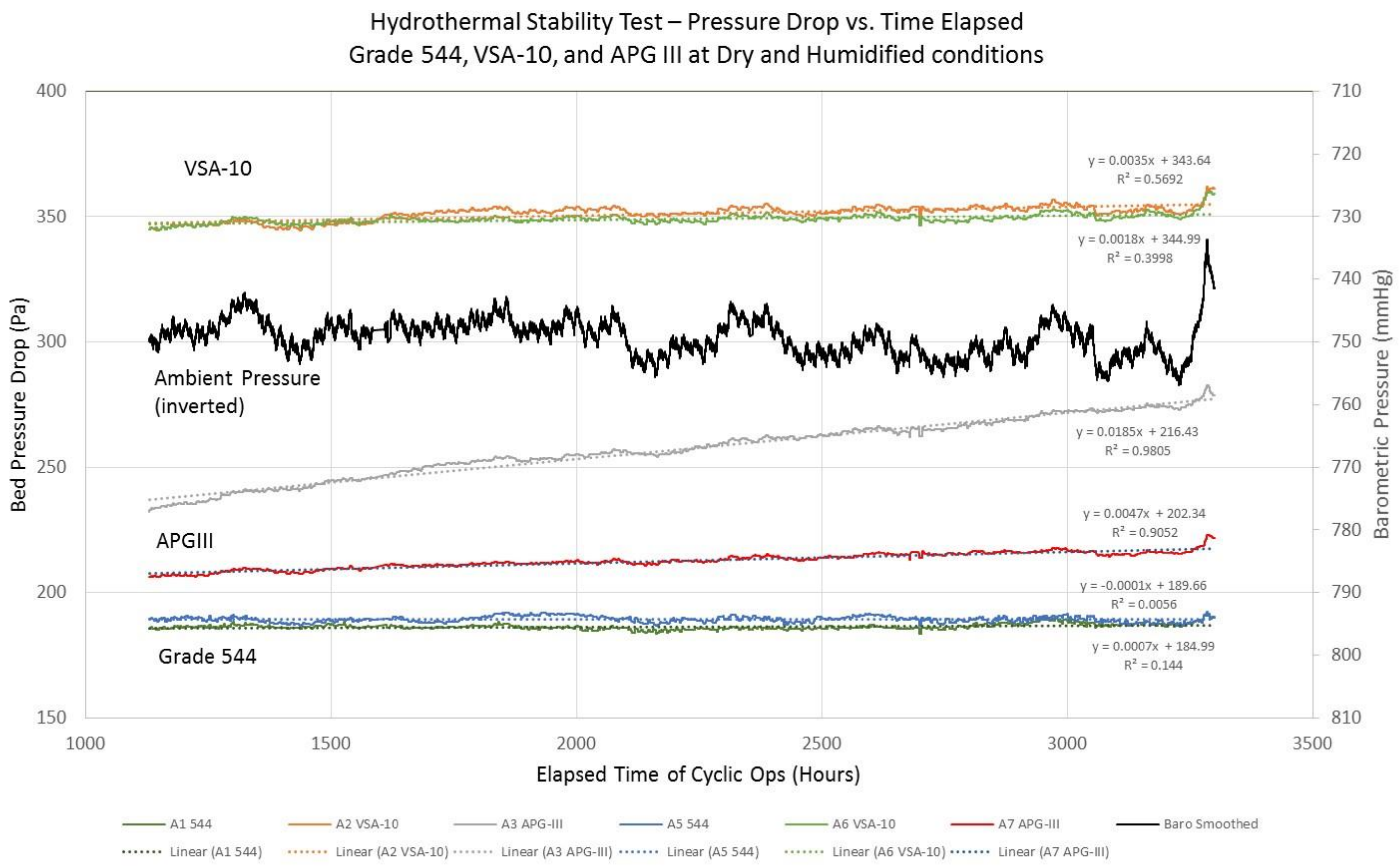


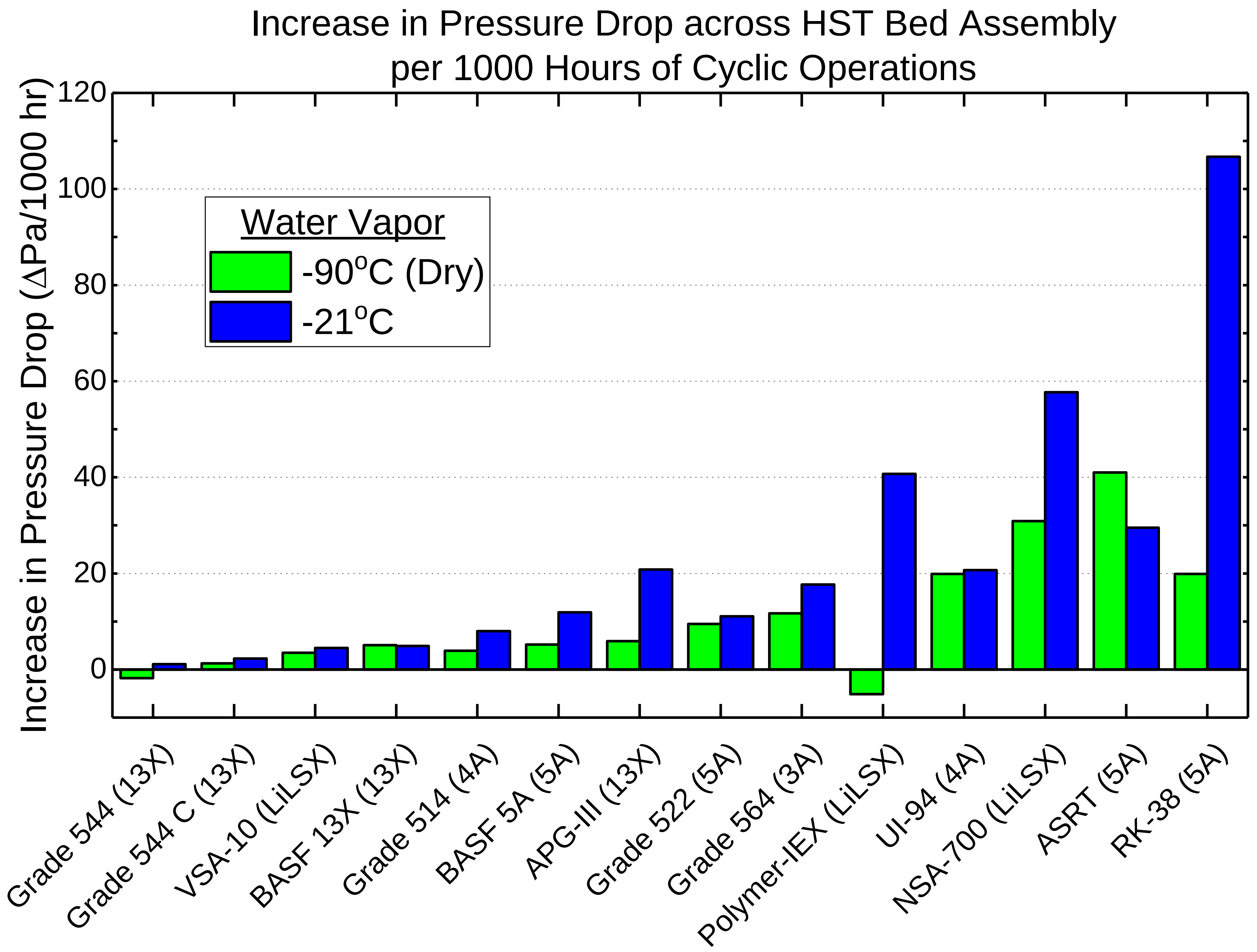




– Target: Outperform current material (ASRT)
   - Two candidates considered from here out are 544 13X and BASF 13X

Sorbent Hydrothermal Stability



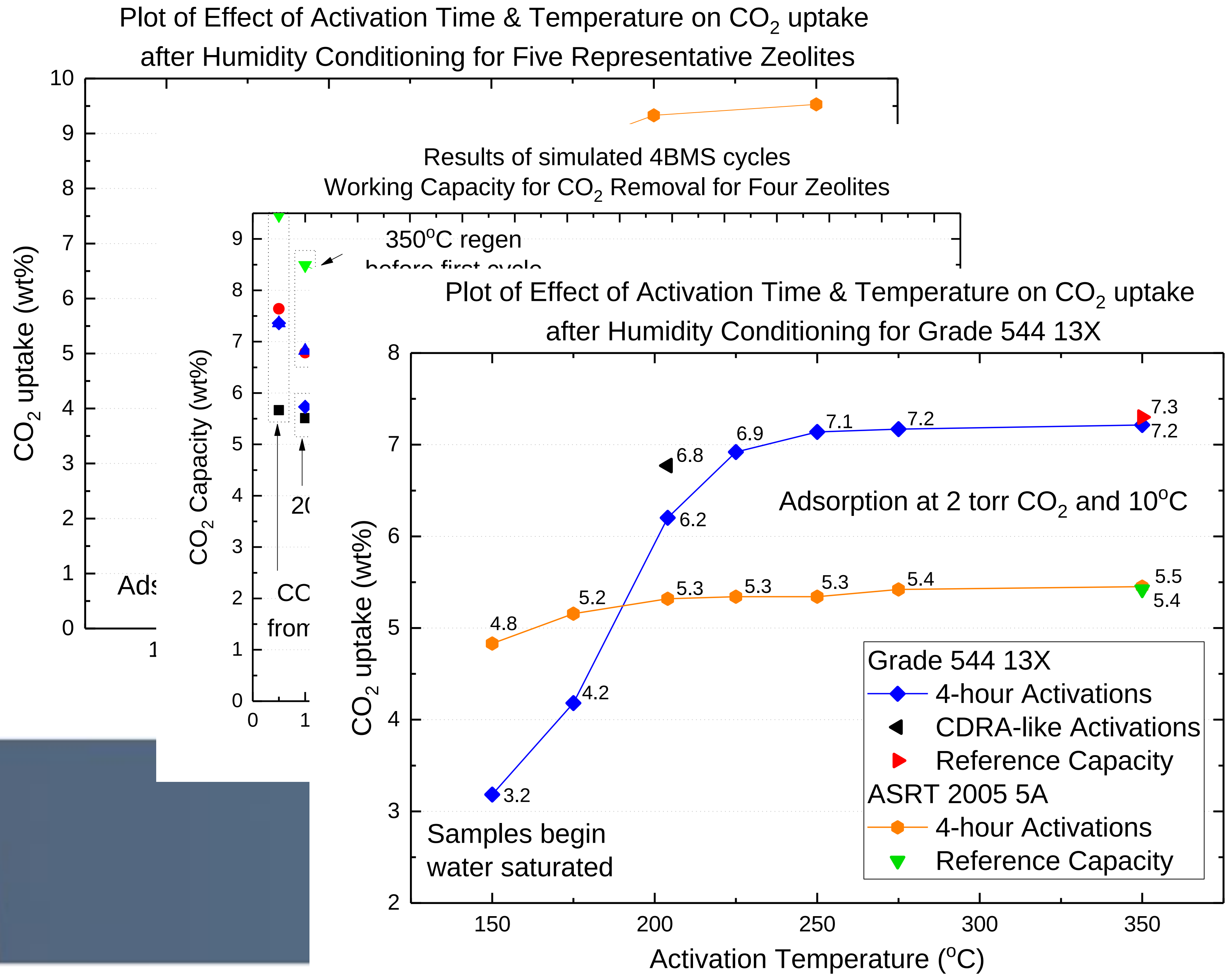


- Target: Minimize filter clogging over time (rising ΔP)
  - Grade 544 13X and BASF 13X perform well

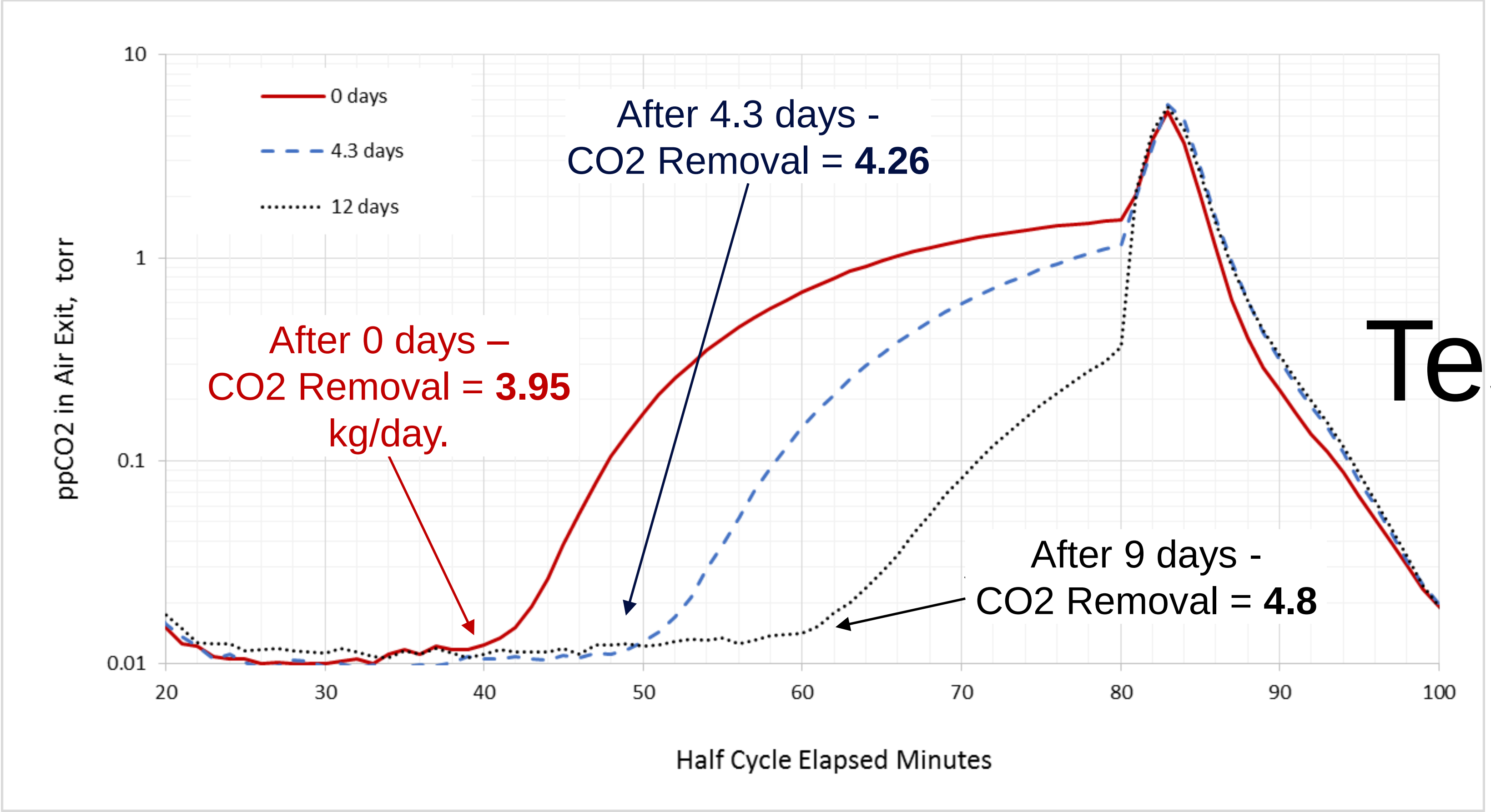
Performance Recovery

– Off-nominal events may include water ingestion into CO_2 sorbent bed
  - Water blocks CO_2 removal performance, though lots of water is required to block entire bed

Subscale Test Predictions



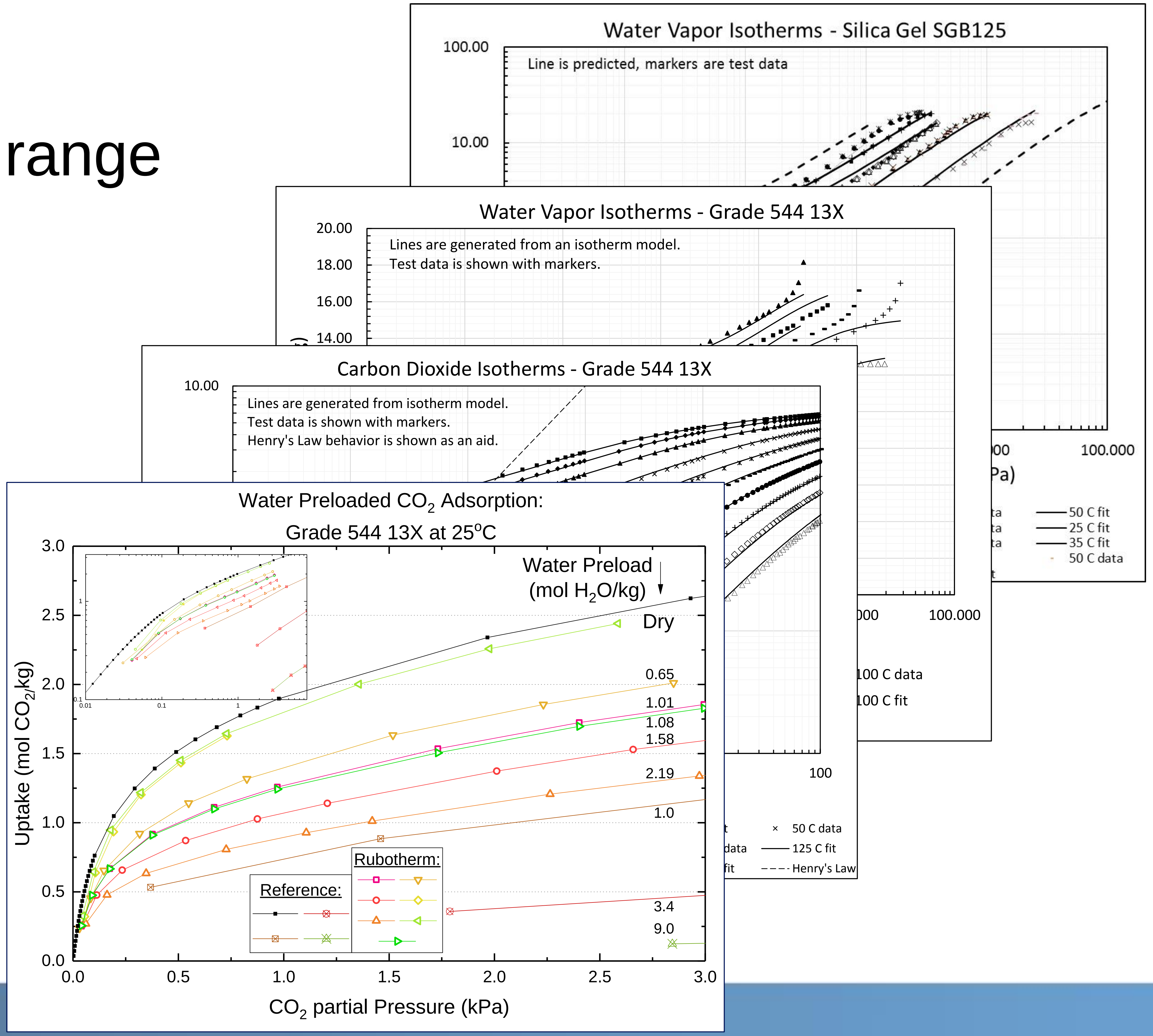
Full Scale Test Results



- What goes into the decision process?
  - Sorbent selection
  - **System sizing**
  - Heater core redesign and optimization
  - Design to address problems at transitions

Sorbent Capacity and Performance

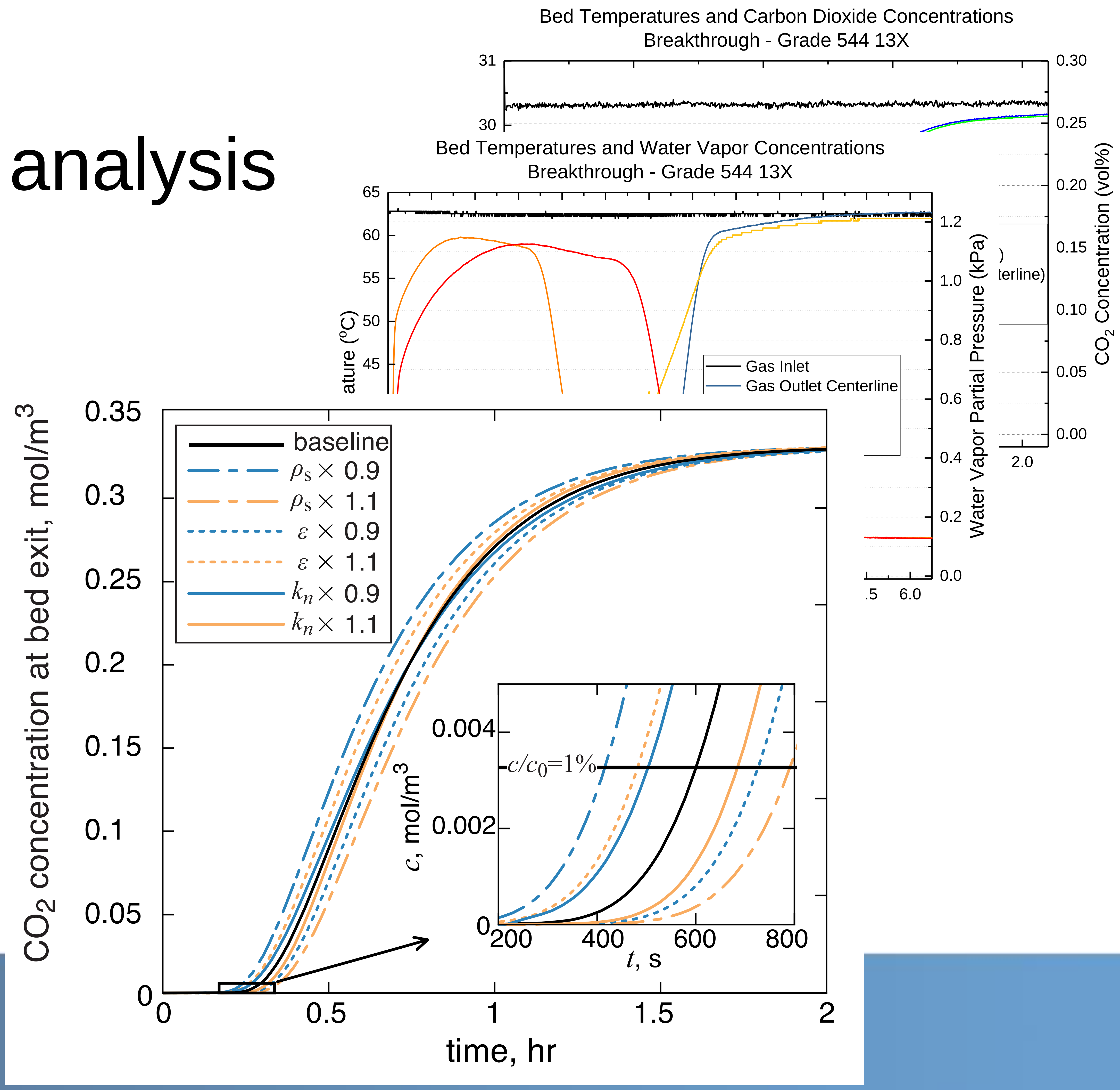
- Capacity for CO_2 and water
  - Across full temperature and pressure range
  - Input to models
- Mixture isotherms
  - Simulation refinement
    - Could optimize system size by 20%



Sorbent Capacity and Performance

- Breakthrough analysis
- NSTF fellow developed sensitivity analysis

Benchtop Tests → Small, One pass, 2-D model → Parameter Determination → Validation against 1-D model → System-scale Cyclic 1-D model → Optimized System



Conclusions

- Redesign is well underway in ES62
  - System capable of scrubbing CO_2 for 4 crew
    - Maintain the newest medical recommendation of 2 torr CO_2
  - Retain proven, high TRL operating architecture
  - Mitigate dust at every turn